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PREGLACIAL GRAVELS ON THE QUARTZITE RANGE NEAR BARABOO, WIS.

WITH SUGGESTIONS AS TO THEIR CORRELATION.

At a number of points on the east bluff of Devil's Lake, and about half a mile from it, at an elevation of 1560 to 1580 feet, A. T., there are traces of gravel differing radically from any other surface formation known in this part of the State. These traces are, in general, very meager, consisting of scattering pebbles only. They may be seen along the crest of the south face of the east bluff for a distance of 80 rods or more, and along the path leading down from the summit of the bluff, in the vicinity of the Devil's Doorway. This path leads over the talus slope of the quartzite range, and the well-rounded pebbles of chert, flint and light-colored quartz are in striking contrast with the purple quartzite blocks over and among which the path-way leads. The pebbles along the path are clearly in secondary positions, having come down from the crest above.

There is a single point, a few rods north of the upper end of the path referred to, where the same sort of gravel may be seen to exist in considerable quantity. The crest of the ridge is here somewhat broad and flat. On its surface a well was dug some years since, and at the site of the excavation, the gravel was found to have a depth of 16 feet, and to rest directly upon the firm surface of the quartzite.

The gravel thrown out in the digging referred to has been subjected to the weathering of many years, but its character does not appear to have been perceptibly modified. It is made up wholly of quartzose material, consisting principally of chert, flint, vein-quartz, and silicified fossils. A glance suffices to show that the larger part of it was derived from limestone formations. In size, the constituents of the gravel range from tiny pebbles to cobbles, three, four, and even five inches in diameter. The

pebbles, especially the smaller ones, are for the most part thoroughly well rounded, though there are occasional conspicuous exceptions. For example, a silicified fossil, such as a fragment of an orthoceras, is now and then found, the form of which is almost perfectly preserved, showing that rounding was not in all cases carried to an extreme degree. Many of the larger pebbles or cobbles are less completely smoothed than the smaller ones, but even these are rarely angular. All, or essentially all, show distinct evidence of having been subjected to very considerable wear. On the whole, the constituents of the gravel are as thoroughly rounded and worn as the constituents of any gravel of similar materials which the writer has ever seen.

Another characteristic of the gravel is the extreme smoothness of its pebbles. While the subangular forms are still retained in some cases, the surfaces even of the subangular pebbles are almost uniformly smooth. Not only this, but many of them, have a sort of gloss or polish which is very unusual, and which could only be acquired by pebbles of extreme hardness.

Among the silicified fossils which enter into the gravel as constituent pebbles, there were found representatives of the following groups: orthoceratites, gastropods, brachiopods, crinoids, bryozoa and corals. The following forms are recognizable:¹ *Astrocerium venustum* Hall, *Favosites niagarensis* Hall, *Fenestella* cf. *termiceps* Hall, *Callopora* cf. *elegantula* Hall, *Retepora* sp. indet., *Zaphrentis* cf. *turbinata* Hall, crinoid trochites, gen. indet., *Orthoceras junceum* Hall. Of all the determinable species, five belong to the Niagara of Wisconsin, and one to the Trenton or Galena.

The quartzite surface immediately beneath the bed of gravel was not seen by the writer, but by those who dug the well it is said to be much worn and polished. Its surface also is said to be marked by very notable pot-holes. This statement can readily be believed, since the surface of the quartzite at various points in the vicinity is seen to be so marked. At one point, at the very crest of the south face, a pot-hole was found about

¹ The determinations were kindly made by Dr. E. C. Quereau.

eighteen inches deep, and about eight inches in diameter. When found, this was nearly filled with soil, but on removing the soil and the vegetation which grew in it, there was found at the bottom of the hole a small amount (a pint or so) of gravel, identical with that at the site of the well.

The fact that the surface of the quartzite on which the gravel under discussion rests, is marked by pot-holes, suggests that the latter were developed when the former were deposited. The pot-holes have been observed before, and have been ascribed to glacial streams descending from the surface of the ice. But the surface where the observed pot-holes and gravel occur is beyond the reach of the ice of the last glacial epoch, and in this region, the ice of earlier glacial epochs is not known to have reached farther west than that of the last. The drift limit, as well as the ice limit in this region, is of exceptionally clear definition, so that it seems certain that the pot-holes are not *moulins*.

It cannot be supposed that the gravel and the pot-holes are the product of glacial waters operating beyond the edge of the ice, first, because the crest of a high ridge where the gravel and pot-holes are, is not the place where extra-glacial waters would run, and, second, because the gravel itself is radically unlike the glacial gravels of the surrounding country, both in its lithological constitution and in its physical condition. If similar materials enter into the constitution of the glacial drift at all, they do so in very subordinate measure. It is incredible that running water, working upon the glacial drift of the region, could bring out of it chert, silicified fossils, quartz, etc., without the slightest admixture of any of the many other constituents which make up the larger part of the drift of the region. The lithological constitution of the gravel is such as to make it altogether certain that it is not glacial, or aqueo-glacial.

The physical condition of the gravel is hardly less conclusive than its lithological constitution, against its glacial or aqueo-glacial origin. The pebbles are rounded and smoothed to a degree altogether beyond that which characterizes the comparable materials of the stratified drift. When the position, the

relation, the constitution and the condition of the gravel are duly considered, there is no escape from the conclusion that it is preglacial.

This preglacial gravel at this elevation and in these surroundings, is surely a striking fact, although it may not now be possible to define its exact significance. It might be thought to be either, first, a remnant of gravel deposited along the course of a former stream, and therefore very local, or, second, a remnant of a formation which was once widespread. Between these two hypotheses it should be possible to decide, if sufficient data are available. While relevant data are less complete than could be desired, they are sufficient to constitute a strong presumption in favor of the latter hypothesis, although the pot-holes, considered by themselves, might seem to point to the opposite conclusion.

It is well known that high-level gravels have a wide distribution in the Mississippi basin south of the limit reached by the ice of the Pleistocene period. Such gravels are well known at various points in the southern part of Illinois, Indiana and Missouri, in Arkansas, Kentucky, Tennessee and in the states further south. Comparable gravels are widespread in the West. In the South these gravels have sometimes passed under the omnibus name Orange Sand. They have sometimes been regarded as of recent (Pleistocene) age,¹ though in late years they have been regarded more commonly as pre-Pleistocene.² It is not to be understood that all the gravels within the general area here referred to are of the same age. Reference is here made especially to the high-level gravels, as distinct from those which occupy the lower lands and the valleys. According to our present interpretation, the gravels which are found capping the hill tops and the high-level plains within the general area specified, represent an older (pre-Pleistocene) formation, while

¹ DANA, *Manual of Geology*, Fourth Edition, p. 964, and UPHAM, *American Naturalist* 1894, pp. 979-988.

² CHAMBERLIN and the writer; *Am. Jour. Sci.*, Vol. XLI., pp. 359-377; 1891. MCGEE; *The Lafayette formation*, Eleventh Annual Report U. S. G. S. CALL; *Arkansas Geological Survey*, Annual Report for 1889, Vol. II. SMITH; *Report on the Geology of the Coastal Plain of Alabama*, 1894.

much of the gravel which occupies the lower lands and the valleys of the same general area, represents a younger formation derived from the older. It is also believed that the valleys and lowlands in which the latter class of gravels are found, were developed by subaërial erosion from the plains on which the high-level gravels occur, after the latter were laid down.

The northward extension of these high-level gravels of the south has never been determined. It has long been known that they reached as far north as Pike and Hancock counties, Illinois.¹

In August, 1891, a paper was read before the Geological Society of America,² in which attention was called to the existence of certain isolated and hitherto unknown beds of high-level gravel, lying farther north than most of those previously known, and believed to be their equivalent. At that time the gravel had been found at various points as far north as Adams county, Illinois, where it was found to underlie the glacial drift. Where the new finds of gravel were made, in Calhoun, Pike and Adams counties, the beds occur, as in the earlier known localities, on the crests of high hills or ridges, or on high plateaus, positions which clearly indicate that the formation was deposited long before the surface had assumed its present topography. Since the gravel underlies the glacial drift of this region at but a few points, and these the most elevated, and since its materials do not enter into the constitution of the glacial drift in any large quantity, there is no room to doubt the conclusion that the high-level gravel of western and southwestern Illinois had been largely removed by erosion before the glacial drift was deposited. Since the amount of erosion involved is large, affecting not only the gravel but also the underlying indurated strata, and since the overlying drift belongs to the earlier part of the glacial period, there is little room to doubt that the gravel is preglacial, and, therefore, according to the commonly accepted standard of classification, pre-Pleistocene.

¹ Geol. Surv. of Ill., Vol. I., p. 331, 1866; Vol. IV., p. 37, 1870.

² SALISBURY; Bulletin of the Geol. Soc. of Am., Vol. III., p. 183, 1892.

The gravel of Adams county is 175 to 200 miles north of the northernmost point where the high-level gravel has any considerable areal development. Within this distance, however, gravel is known at many points. At all these points its constitution, its physical condition, and its geological and topographical relations are such as to leave little room to doubt that the existing beds are to be correlated with each other, and that they are the erosion remnants of a once continuous formation, which extended over southern Illinois, reaching at least as far north as Adams county.

The study of the high-level gravels of adjacent states had at that time (1891) left no room to doubt their correlation with the similar formations of Illinois. It is confidently believed that the gravels on the crest of Crowley's ridge in Arkansas, and its continuation northward into Missouri, are parts of the same formation which once covered the southern portion of Illinois, and considerable parts of Kentucky and Tennessee. To the south, this formation probably extended to the gulf. Its extreme eastward and westward borders, as originally developed, have not been determined, but in both directions the extension was great. In Indiana it is known to have reached as far east as Perry¹ county. The possibility should be recognized that these high-level gravels may not all belong to one formation, although the remnants thus far referred to in Indiana, Illinois, Missouri and Arkansas are so similar in constitution and in all their relationships as to raise a presumption in favor of this view.

At the time of the reading of the paper cited above, the gravel had not been found at any place north of Adams county, Illinois. In spite of this fact, it was believed that the formation once extended further north since its materials, so it was thought, were to be recognized as minor constituents of the glacial drift at various points as far north as Rock Island county. If this identification be correct, it means that at the time of the deposition of the drift in Rock Island county, remnants of this preglacial gravel formation were still in existence as far north as that point. The localities in this county where material

¹ Bull. Geol. Soc., Vol. III., 1892, p. 186.

derived from the pre-Pleistocene chert gravel were thought to enter as constituents into the drift, are 100 to 125 miles north of the northernmost point in Adams county, where the formation is known to occur *in situ*. At many intermediate points, similar materials were found in the glacial drift. Quantitatively they are unimportant, and their absence is more common than their presence. Their occurrence and distribution in the drift are such as would have resulted had erosion remnants of the high-level gravel existed when the ice invaded western Illinois.

In the paper referred to it was stated that certain limited beds and scattered remnants of hitherto unexplained quartzose gravel were known to exist within the driftless area of Wisconsin, and the suggestion was hazarded that these gravel remnants were very likely to be correlated with the gravels further south. The remnants of gravel in Wisconsin occur at various points from Crawford county on the south, to Dunn county on the north. Wherever known, these remnants occur on the crests of ridges and the summits of isolated hills. Not only this, but they are found on the summits of the highest elevations of the region within which they occur. They often consist of nothing more than scattering pebbles, though beds a few feet in thickness are known, the most considerable being near the village of Seneca in Crawford county. The gravel is here composed almost wholly of quartz.¹ As at various points further south, the gravel is here cemented by iron oxide into a firm conglomerate. The average depth does not appear to be more than five or six feet, but it has been penetrated to very much greater depths at one or two points. The exceptional depths are thought to represent the fillings of fissures, which affect the underlying rock.

Had gravel remnants similar to those of the driftless area existed in western Illinois at the time this region was glaciated, they would have contributed to the drift of their respective localities, just such material as it has been observed to contain. They would have made considerable contributions where they were considerable, and meager contributions where they were

¹ STRONG, Geology of Wisconsin, Vol. IV., p. 88.

meager. The facts, (1) that the pre-Pleistocene gravel exists in the form of widely separated erosion remnants south of the drift-covered country; (2) that isolated remnants of it are known to exist at several points beneath the drift, as many as 125 miles north of the southern limit of glaciation (Adams and Hancock counties); (3) that the glacial drift here and there at various points for 90 miles further north (Rock Island county) contains gravel which might well have come from remnants of the northern extension of the same formation; (4) that remnants of similar gravel occur in the driftless area, where there has been no chance of destruction or burial by the ice; and (5) that the gravel in all these situations has the same topographical habit, all point to the conclusion that they are parts of a once widespread and continuous gravel formation.

The gravel on the east bluff of the Devil's Lake is about 60 miles east of the gravel of Crawford county. It is about 150 miles northeast of that part of Rock Island county where similar gravel is a local constituent of the glacial drift. The topographic situation of the gravel is the same as that of all the widely distributed remnants further west and south, to which reference has already been made. In its constitution and other physical characteristics, the Devil's Lake bluff gravel is so similar to that of the region farther south (Adams county, Illinois, etc.), that it could hardly fail to recall the southern formation to one who had seen it in southern Illinois, Missouri and Arkansas. The geographic and topographic position of the Devil's Lake gravel, as well as its constitution and physical condition, make it altogether rational to infer that it may have been connected with the isolated beds of similar material already referred to, and that, as originally developed, the formation of which the existing beds are but remnants, had a much greater extension than has heretofore been recognized. If the gravel on the bluff east of Devil's Lake be a remnant of an extensive preglacial gravel formation, it becomes a matter of much importance to fix its age.

Limited occurrences of somewhat similar gravel or ferruginous conglomerate are known in southeastern Minnesota, and

have been referred, with some doubt, to the Cretaceous.¹ On the other hand, its relations are so uncertain as to have led to the suggestion that it may represent a remnant of the Oriskany sandstone.² It is clear that if its relations to the underlying strata do not preclude its reference either to the Oriskany or to the Cretaceous, they do not preclude its reference to the Tertiary. Since it is overlain by glacial drift only, it would not seem that there is anything in its relations to superior strata to preclude its reference to the Oriskany, the Cretaceous, or the Tertiary. Similar gravel in Fillmore county is unhesitatingly referred to the Cretaceous,³ because of its association with certain clays containing Cretaceous fossils.

The topographic relations of the gravel and conglomerate of Minnesota here referred to, are the same as those of similar deposits in the driftless area of Wisconsin, and the suggestion is here renewed that they probably go together, and that they are very likely to be correlated with the high-level gravels further south.

Conglomerate which may be found to belong with the gravel and conglomerate of Minnesota, Wisconsin, Illinois, and regions further south, is known to exist at Rockville, Iowa. This was referred to by McGee⁴ in 1879, as belonging to the glacial series.

In the Devil's Lake gravel there is nothing, so far as known, to fix its age. It rests unconformably on Algonkian rock, and it is evidently preglacial. It contains silicified fossils, which seem to have been derived chiefly from the Niagara limestone. Internal evidence, therefore, does not prohibit the reference of the gravel to any period between the Niagara and the Pleistocene. If this gravel is to be correlated with the gravels of southern Illinois, it is doubtless late Tertiary. On the other hand, there is no inherent evidence which precludes its reference to the Cre-

¹ Final Report Geol. and Nat. Hist. Surv. of Minn., Vol. I., pp. 305-309.

² Loc. cit., pp. 355-6.

³ Loc. cit., pp. 307-11.

⁴ Geological Magazine, Vol. VI, 1879, p. 360-1.

taceous,—the reference which Professor Winchell has suggested for the high-level preglacial gravels of southern Minnesota. Assuming that the Minnesota gravel referred to is Cretaceous, and comparing the Devil's Lake gravel with that of Minnesota alone, this would perhaps seem to be the most natural reference of the Wisconsin beds.

It is not beyond the range of possibility that some of the gravel beds here mentioned are Cretaceous, while others are Tertiary. The gravel beds of Minnesota and Crawford county, Wisconsin, resemble each other much more closely than either resembles the Devil's Lake bluff gravel. The Devil's Lake gravel, on the other hand, is strikingly like that of the areas further south, and on the ground of physical likeness would be classed with it, rather than with the beds of Crawford county, Wisconsin, and of southeastern Minnesota. It is distinctly recognized, however, that physical likeness is not a safe criterion from which to draw important conclusions. Both in Crawford county and at Devil's Lake, the gravel is unaccompanied by the clay and sand beds which are present in Minnesota, and on the basis of which the Cretaceous correlation was suggested. At various points in western and southern Illinois, on the other hand, clay exists immediately beneath the gravel; the same is true in some parts of Missouri. So far as known, no determination of the age of the clay of these regions has been made, nor is it known that the clay and the overlying gravel belong to the same period. So far as association with clay is concerned, the gravel of southeastern Minnesota would seem to belong with the gravel of western Illinois (Pike and Adams counties). Manifestly little weight can be attached to this association, on the basis of present knowledge.

There is some reason for believing that there may be both late Tertiary, and older (possibly Cretaceous) gravel formations south of the Ohio River. The gravel between the Cumberland and the Tennessee Rivers, exposed in the deep railway cut, may represent a formation much older than the gravel of Adams county, Illinois, or of Crowley's ridge, Arkansas. It is not to be

looked upon as impossible, therefore, that both Cretaceous and Tertiary gravels may have extended as far north as Wisconsin. If so, it is possible that remnants of both still exist, though until we have positive evidence of two formations, the presumption is in favor of but one.

Whatever the age of the Devil's Lake gravel, its topographic position is full of significance. It occurs on one of the highest points of the state. Within the driftless area, where such gravel as this might have escaped destruction if it ever existed, there is, we believe, but one other point so high as that on which the gravel occurs. This is the Blue Mounds. On the crests of these mounds, corresponding gravel is not known to occur, though they have never been examined, so far as known, with this point in view.

It is clear that the gravel could not have been deposited in its present position, since the existing topography was developed. The ridge on which it occurs is about 700 feet higher than the Baraboo River to the north, and about 800 feet higher than the Wisconsin River to the south, and, what is still more significant, it is 500 or 600 feet above the general level of the extensive drift-covered sandstone plain which surrounded it. Since the gravel is not glacial, there is but one interpretation possible concerning the topographic conditions and relations at the time it was deposited. At that time the surface on which it occurs was not higher than its surroundings. This fixes the age of the gravel in terms of erosion. It was deposited before the quartzite ridge was isolated, that is while the Potsdam and later formations still reached the top of the harder quartzite.

The amount of erosion which has been accomplished since the gravel was deposited is, therefore, very great. It should be noted that this erosion is not measured simply by the excavation of valleys on either hand to the depth of 700 and 800 feet respectively. Since the gravel was deposited, the general surface of the surrounding country has been cut down to the extent of 500 to 700 feet, disregarding the heavy drift deposits which have helped to build it up again. This building up process was con-

siderable, for there can be no question but that in this region glacial deposition greatly exceeded glacial erosion. The quartzite range is not simply an inter-stream ridge; it is an elongate monadnock standing up out of a very extensive peneplain. The amount of erosion necessary to isolate it was much greater, and demanded a very much longer period of time than would have been necessary simply to cut valleys 700 or 800 feet deep. Looked at from this standpoint, one is inclined to think that the age of the gravel may be as great as Cretaceous. On the other hand the total amount of erosion which has taken place in the upper Mississippi basin since the deposition of the gravel is but a fraction of that which is believed to have taken place in some parts of the west in late Tertiary and post-Tertiary time.

Although the topographic relations of the gravel do not enable us to fix its age in the accepted terms of geological chronology, they seem to bring out the general fact that the present physical features of the upper Mississippi basin are of later origin than has been generally supposed. This is especially true if the gravel shall prove to be Tertiary, and the balance of evidence seems at present to favor this interpretation.

There is still another direction in which the gravel bed at Devil's Lake is of interest. The fossil content of the gravel, as well as the greater quantity of chert, indicates that it was derived in considerable part from the Niagara limestone. It has long been believed that the Niagara limestone of Wisconsin, now confined principally to the eastern margin of the state, once extended much farther west, over regions whence it has been removed. The constitution of the gravel affords an interesting confirmation of this belief, and seems to indicate that the Niagara may have had even a greater extent than has been supposed, for it can hardly be doubted that, when the gravel was formed, the limestone either overlay the quartzite, or existed at some equally high point in the immediate vicinity. Not only this, but the presence of one fossil, *orthoceras junceum*, which, so far as known, can be referred only to the Trenton or Galena, suggests that one or both of these formations also once passed over the quartzite

ridge, or at least that they were once at equally high points in the immediate vicinity. If these formations once covered the quartzite and were overlain by the Hudson River shale, the Niagara limestone, which, in Wisconsin, immediately succeeds the Hudson River shale, must have originally lain very high above the crest of the quartzite range. If the Trenton lay upon the quartzite directly, and if it and the succeeding Galena and Hudson River formations had their usual thickness, the base of the Niagara could hardly have been less than 500 feet above the top of the east bluff at Devil's Lake. If the St. Peters sandstone and the lower Magnesian limestone overlay the quartzite beneath the Trenton, the base of the Niagara must have been still higher.

R. D. SALISBURY.